Decoding the Amplitude-Modulated Part the DCF77 Longwave Time Signal by using the Goertzel Algorithm

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***Abstract*—The DCF77, a long wave time signal transmitter that is located near Frankfurt am Main in Germany, is the primary source of time information for radio-controlled clocks in Europe. Its signal consists of a phase and an amplitude-modulated part, both containing the time information. Devices that use the signal usually consist of an amplitude modulation long wave receiver, often realized by using a dedicated integrated circuit, and an application processor. In this paper, an alternative approach for the demodulation of the amplitude-modulated part of the signal, without the need for specialized analog cicruitry and only a minimal amount of simple hardware components, is presented. This is done by utilizing direct-sampling software-defined radio techniques together with leveraging the efficiency of the Goertzel algorithm. As a result, the presented approach removes the need for most of the usually employed analog circuitry, leaving only a front-end amplifier, and therefore effectively proposes a new type of design where the receiver is implemented inside the application processor. The employed lightweight algorithms keep it realizable on a system with limited resources, which is shown in an example implementation on a Arm Cortex-M3 microcontroller.**

***Index Terms*—DCF77, Goertzel, Digital Signal Processing, Time Signal, Software Defined Radio**

I. Introduction

Radio controlled clocks are very popular because they dont require periodical re-adjustment in comparison to common mechanical or quartz-powered clocks. Instead, the information about the current time is obtained from a RF-signal that is transmitted by an official authority that ensures its availability and correctness. The probably most important time signal in Europe is transmitted by the station DCF77 from Mainflingen, a city in Germany that is close to Frankfurt am Main. The station is operated by a private company that is commissioned by the Physikalisch-Technische Bundesanstalt (PTB) which also supplies the current time information, generated by two caesium clocks and two caesium fountains. Its operating frequency lies in the long wave area at $77.5\,\mathrm{kHz}$ and the time signal uses simple modulation techniques (amplitude and phase-modulation) and transmits with $100\,\mathrm{kW}$ Effective Isotropic Radiated Power (EIRP) to enable the reception of the signal in relatively close distances (up to $2000\,\mathrm{km}$) with simple technical equipment [2].

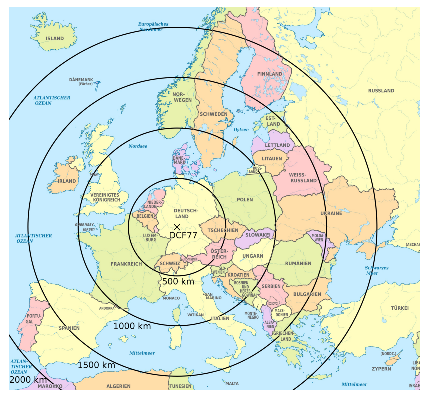

Fig. 1. Coverage of the DCF77 signal. Adapted from [1]

End-user devices usually make use of the amplitude-modulated part of the signal by using an amplitude modulation receiver, often a by employing specialized integrated circuit, together with a rather big ferrite-rod antenna to obtain the time signal. This time signal then needs further hardware, often in form of a microcontroller used as the applicaton processor, to decode and retrieve the actual time information. With the increasing availability of computation power and Digital Signal Processing (DSP) capabilities inside cheap mixed-signal microcontrollers, which are already used to process the time information, the idea to replace to replace the analog receiver portion with a Software Defined Radio (SDR) is more or less obvious. Moving the receiver into the application processor would allow for a simpler hardware design by shrinking down the complexity and the parts count of the external analog circuitry. In fact, only a tuned antenna with a basic pre-amplifier is needed.

In this paper, a straightfoward principle for designing a lightweight receiver for the DCF77, based on SDR-techniques, is presented. After taking a look at the structure of the DCF77 signal, the theoretical operation principle of the receiver is explained and shown in a MATLAB simulation. To further underline the simplicity and the possibility to implement the principle on a system with limited resources, a demonstration on a Arm Cortex-M3 microcontroller is shown.

II. The DCF77 signal

The DCF77 station operates in the long wave area at a frequency of $77.5\,\mathrm{kHz}$. Its operation started with transmitting a frequency standard in 1959. In 1973, the transmission of the current time information was added to the signal by using amplitude modulation. To allow a reception under more challenging conditions and with a higher resolution and accuracy, the same time information is also added to the signal since 1983 by using phase-modulation [3]. The two different parts of the signal that result out of the parallel amplitude and the phase-modulation can be used for different use-cases that are separated by the requirements regarding the resolution, accuracy, and the reliability of the obtained time information. Whereas the amplitude-modulated part is mainly used for general-purpose time application with low resolution requirements, the phase-modulated part is usually used for specialized applications that require a higher resolution, accuracy, and reliability. Although being considered as low in comparison to what is achievable by analyzing the phase-modulated part, the usually observed accuracy uncertainity when using the amplitude-modulated part it is still well below $1\,\mathrm{s}$, being $100\,\mathrm{ms}$ [2]. When using the phase-modulated part, a standard deviation of $\pm 2\,\mu\mathrm{s}$ to $\pm 22\,\mu\mathrm{s}$ from the atomic clock to the receving device can be observed [4].

As the amplitude-modulated part allows simplistic receiver designs through its straightfoward modulation scheme, it is used in the principle presented in this paper and a focus is put on explaining this part of the DCF77 signal.

III. Principle of a DCF77 receiver

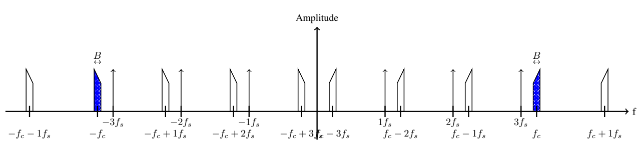

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TABLE I
TABLE TYPE STYLES

Table Head	**Table Column Head**		
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[a]Sample of a Table footnote.

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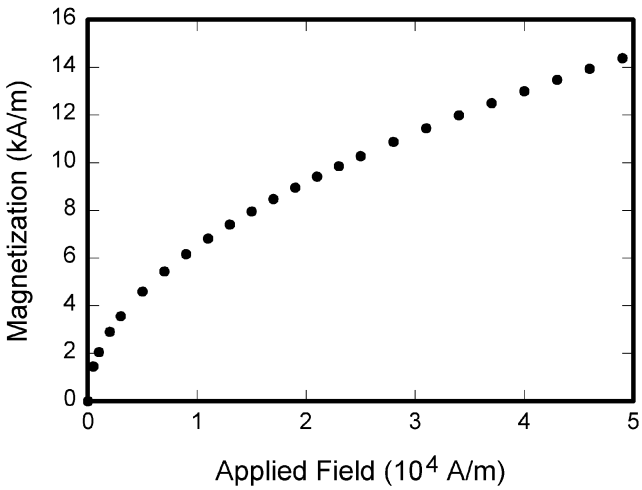

Fig. 2. Example of a figure caption.

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ACKNOWLEDGMENT

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REFERENCES

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